Particle Flow Isolation for a SUSY analysis

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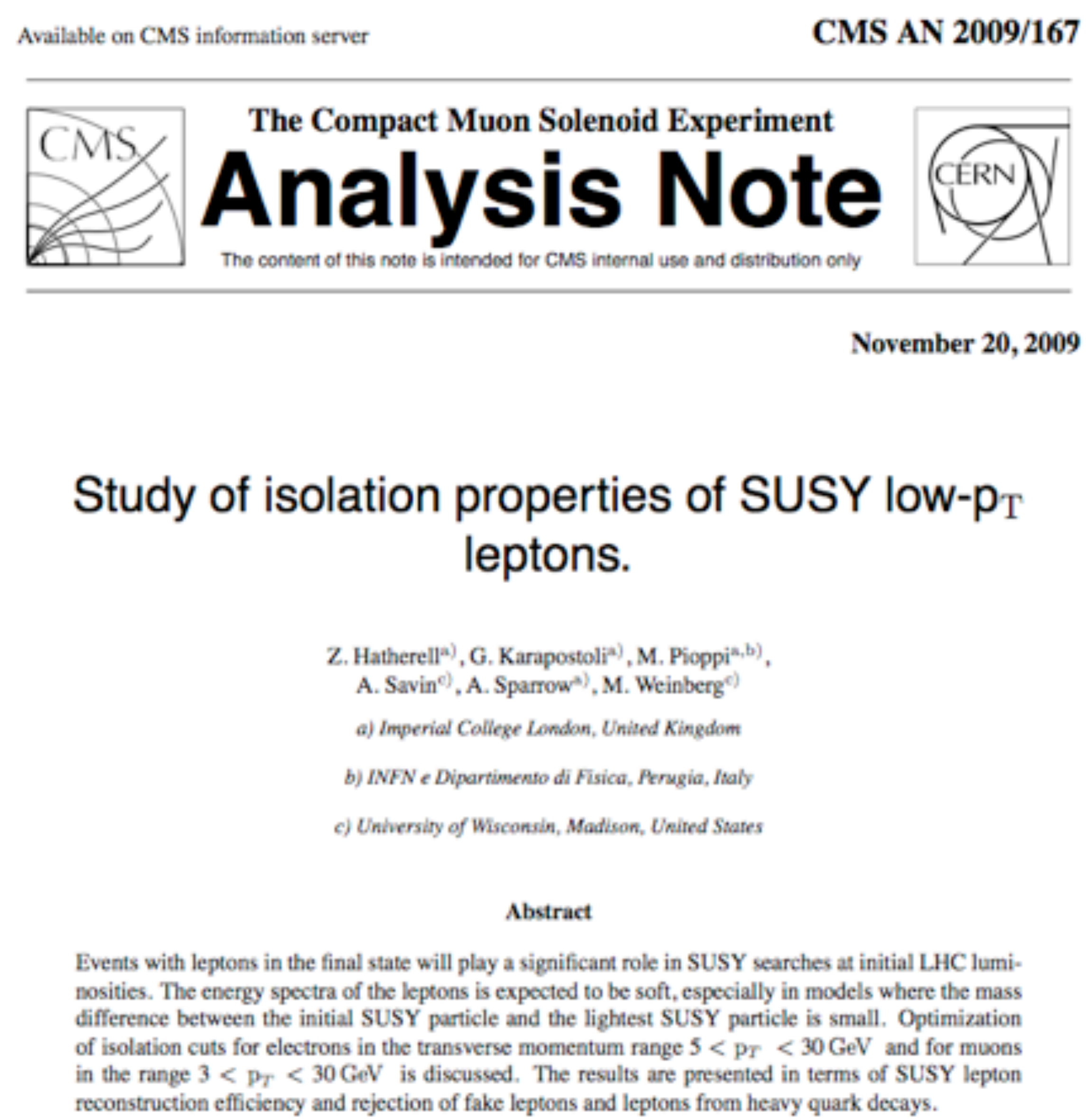
Outline

- Motivation
- Technical Details
- Event selection
- Isolation used
- Optimisation
- Optimisation approaches
- SUSY results
- Conclusions

Motivation

- We wanted to see the impact of Particle Flow in the search for SUSY in the leptonic channels, in particular of particle flow leptons.
- We wanted to compare Particle Flow vs Standard RECO performance.
- There is a lepton isolation study done in the Standard RECO framework, we wanted to reproduce it from the Particle Flow point of view (CMS AN 2009-197).



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CMS AN 2009/167

The Compact Muon Solenoid Experiment

Analysis Note

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November 20, 2009

Study of isolation properties of SUSY low-p_T leptons.

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Abstract

Events with leptons in the final state will play a significant role in SUSY searches at initial LHC luminosities. The energy spectra of the leptons is expected to be soft, especially in models where the mass difference between the initial SUSY particle and the lightest SUSY particle is small. Optimization of isolation cuts for electrons in the transverse momentum range $5 < p_T < 30$ GeV and for muons in the range $3 < p_T < 30$ GeV is discussed. The results are presented in terms of SUSY lepton reconstruction efficiency and rejection of fake leptons and leptons from heavy quark decays.

Technical Details

PAT production

- CMSSW_3_1_4
- PAT Layer1 V6 recipe as appears at https://twiki.cern.ch/twiki/bin/view/CMS/SusyPatLayer1DefV6

Samples Used

- /LM0/Summer09-MC_31X_V3_7TeV-v1/GEN-SIM-RECO
- /LM1/Summer09-MC_31X_V3_7TeV-v1/GEN-SIM-RECO
- /InclusiveBB_Pt30/Summer09-MC_31X_V3_7TeV-v1/GEN-SIM-RECO
- /QCD_Pt250to500-madgraph/Summer09-MC_31X_V3_7TeV_preproduction-v1/GEN-SIM-RECO
- /QCD_Pt500to1000-madgraph/Summer09-MC_31X_V3_7TeV_preproduction-v1/GEN-SIM-RECO
- /QCD_Pt1000toInf-madgraph/Summer09-MC_31X_V3_7TeV_preproduction-v2/GEN-SIM-RECO
- /TTbarJets-madgraph/Summer09-MC_31X_V3_7TeV-v2/GEN-SIM-RECO
- /WJets-madgraph/Summer09-MC_31X_V3_7TeV_preproduction-v1/GEN-SIM-RECO

PF2PAT production

- CMSSW_3_3_2
- PF2PAT recipe posted on Nov 17 2009 at https://twiki.cern.ch/twiki/bin/view/CMS/WorkBookPF2PAT#3_3_2

Used Objects

Only PAT objects were used for both cases Standard RECO and Particle Flow.

Jets Cleaned

A cleaning was applied for the Standard RECO Jets so that there were no double counted electrons.

Event requirements

SUSY has a very dense environment therefore a cut in H_T > 300 GeV requiring Jets with Pt > 50 GeV was applied.

Lepton classification based on MC

- “Prompt” leptons, originated by SUSY decay particles, a W/Z or a Tau.
- “Heavy Flavor” leptons, coming from hadronic decays of heavy flavor particles (b/c).
- “Fake” leptons, did not have any corresponding lepton at the truth generated level.
- MC truth was done using a $\Delta R < 0.5$

$$\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$

Electron Selection

- Pt > 2 GeV
- $|\eta| < 2.5$
- Transverse impact corrected for the beam spot < 2mm

Muon Selection

- Pt > 2 GeV
- $|\eta| < 2.1$
- Transverse impact corrected for the beam spot < 2mm
- Normalized global $\chi^2 < 10$
- Number of hits in the tracker track > 11
- The cuts in red were applied in order to reduce the contributions from heavy flavour and fake leptons

Isolation Calculation

PAT leptons were produced using this isolations

Standard RECO

$$Iso_{abs}^{track} = \sum_{\Delta R<0.3} P_T^{track}$$

$$\downarrow$$

$$Iso_{abs}^{ECAL} = \sum_{\Delta R<x} E_T^{ECAL} \rightarrow \begin{cases} x = 0.3 & \text{if } \mu \\ x = 0.4 & \text{if } e \end{cases}$$

$$\downarrow$$

$$Iso_{abs}^{HCAL} = \sum_{\Delta R<x} E_T^{HCAL} \rightarrow \begin{cases} x = 0.3 & \text{if } \mu \\ x = 0.4 & \text{if } e \end{cases}$$

$$\downarrow$$

$$Iso_{abs}^{comb} = \sum_{\Delta R<0.3} P_T^{track} + \sum_{\Delta R<x} E_T^{HCAL} \rightarrow \begin{cases} x = 0.3 & \text{if } \mu \\ x = 0.4 & \text{if } e \end{cases}$$

Particle Flow

$$PFIso_{abs}^{ChargedHadrons} = \sum_{\Delta R<0.4} P_T^{PFChargedHadrons}$$

$$\downarrow$$

$$PFIso_{abs}^{NeutralHadrons} = \sum_{\Delta R<0.4} P_T^{PFNeutralHadrons}$$

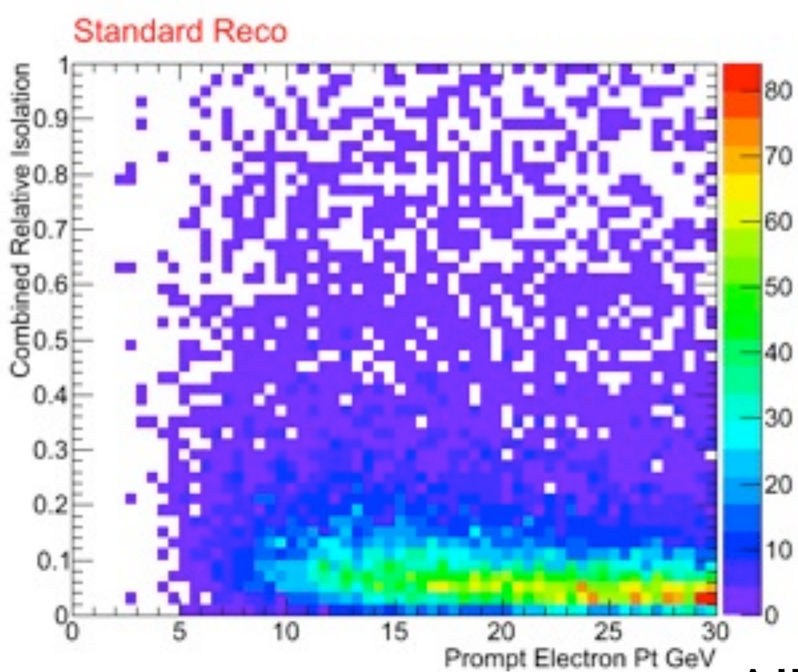
$$\downarrow$$

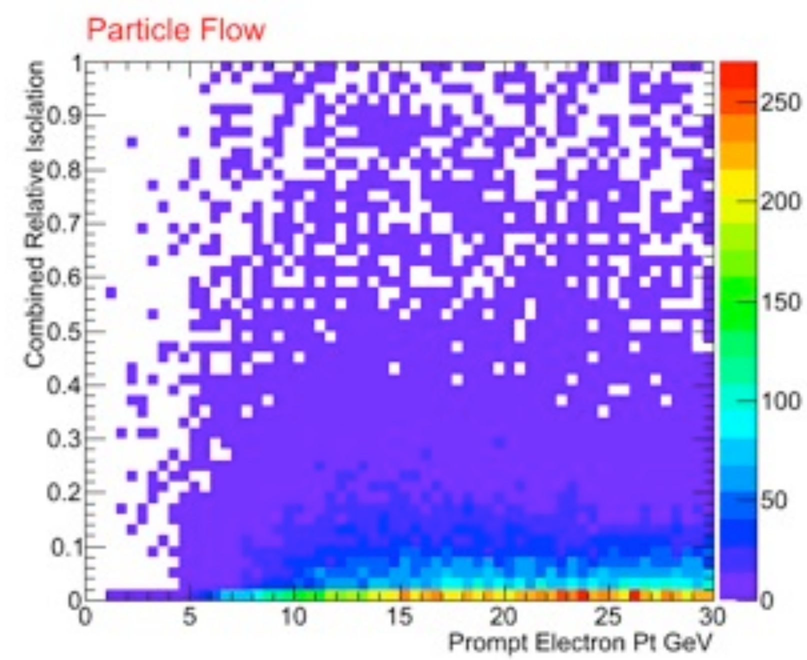
$$PFIso_{abs}^{Gamma} = \sum_{\Delta R<0.4} P_T^{PFPhotons}$$

$$\downarrow$$

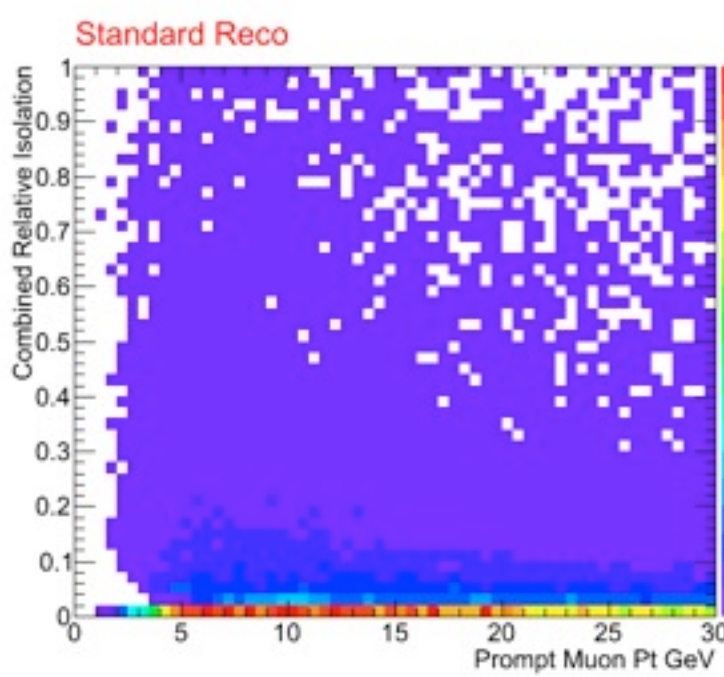
$$PFIso_{abs}^{comb} = \sum_{\Delta R<0.4} P_T^{PFPhotons} + \sum_{\Delta R<0.4} P_T^{PFChargedHadrons} + 0.333 \sum_{\Delta R<0.4} P_T^{NeutralHadrons}$$

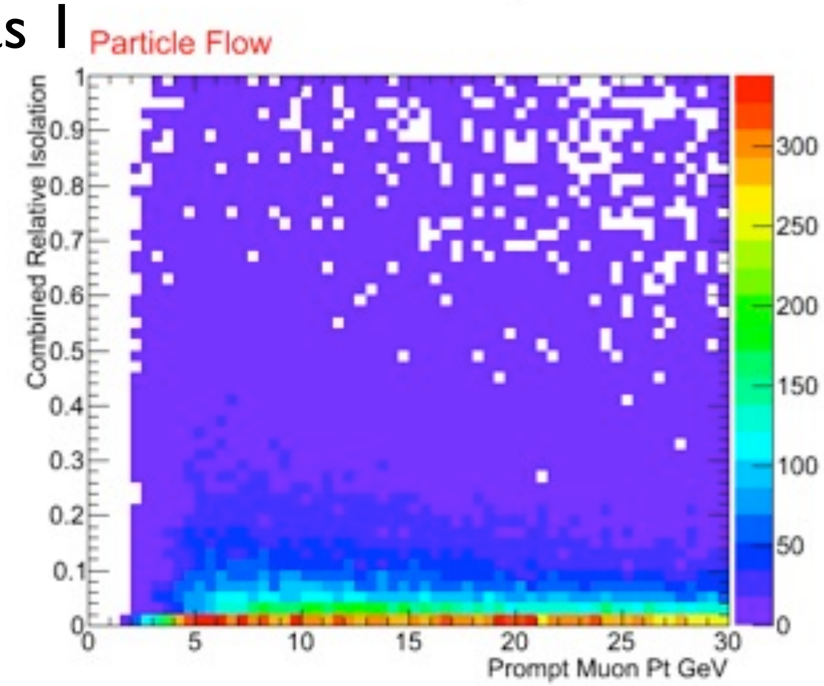
Combined Relative Isolation Prompt





All weights taken as 1



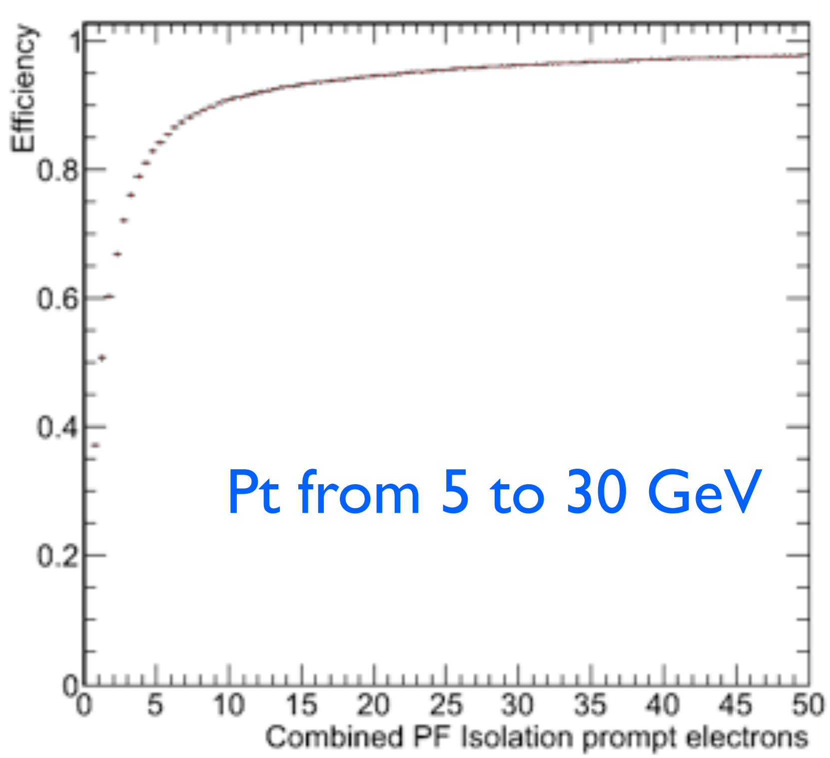


Optimisation

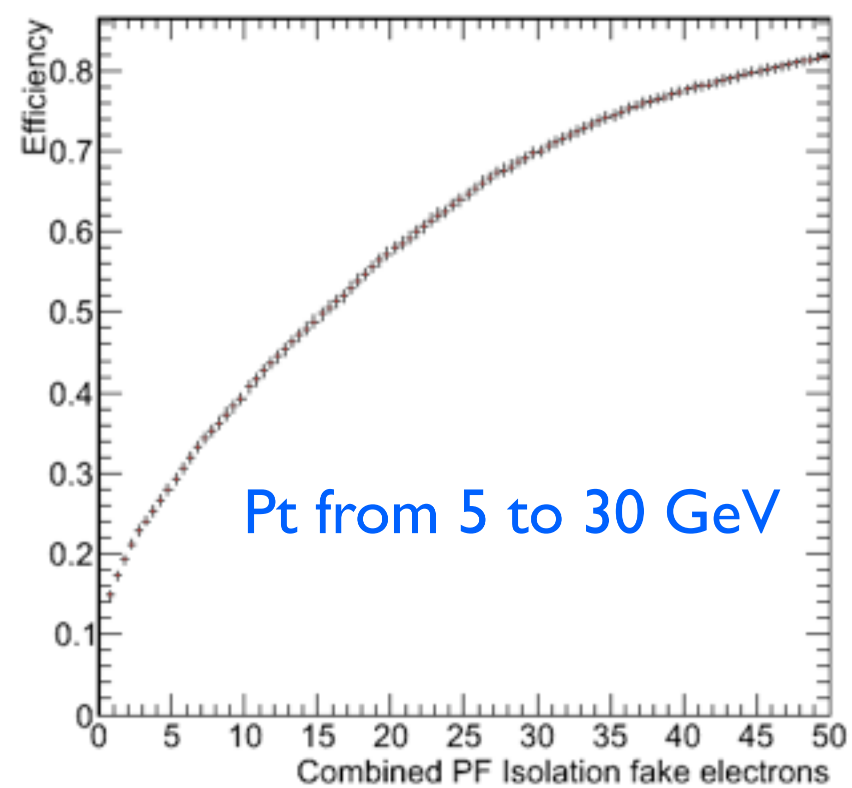
- We divided the leptons by their Pt in ranges of 3 GeV from 0 to 30 GeV.
- For each of these ranges we calculated the efficiency of detection as a function of isolation, we considered the four possible cases:
  - Particle Flow:
    - Gamma Isolation, Charged Hadron Isolation, Neutral Hadron Isolation.
  - Standard RECO:
    - Track Isolation, ECAL Isolation, HCAL Isolation.

$$Eff = \frac{\text{Number of leptons}(Iso, P_T)}{\text{Total number of leptons}(P_T)}$$

$$rej(Iso) = 1 - Eff(Iso)$$



VS



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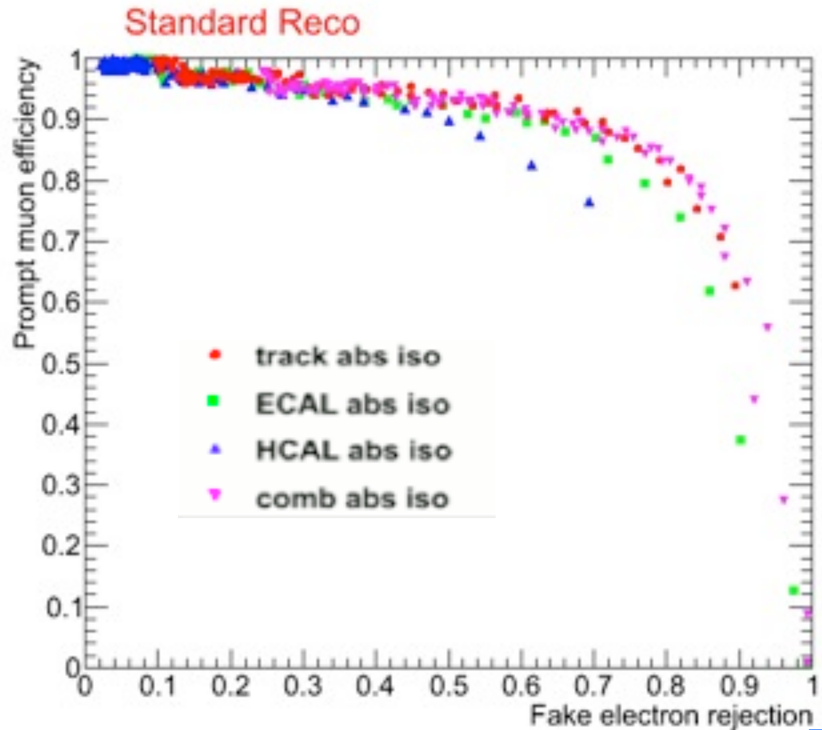
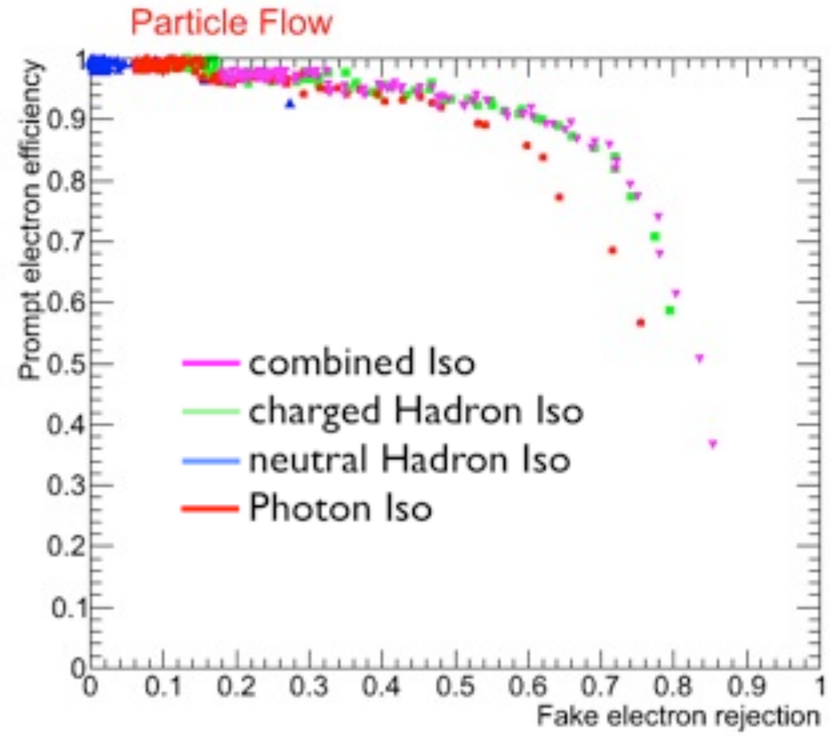
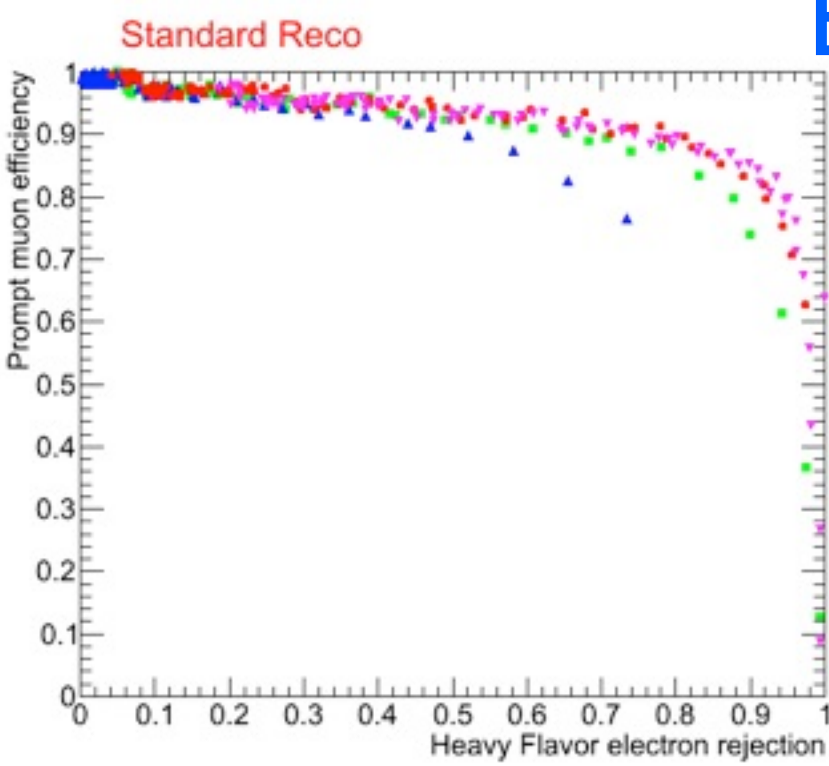
Efficiency vs Rejection

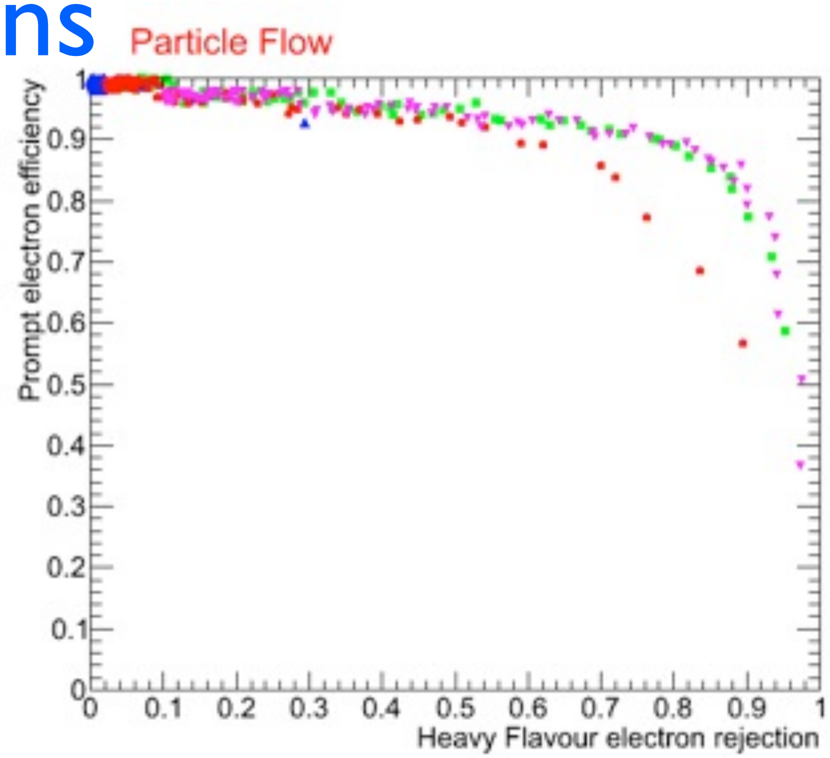
Pt from 5 to 30 GeV





Electrons





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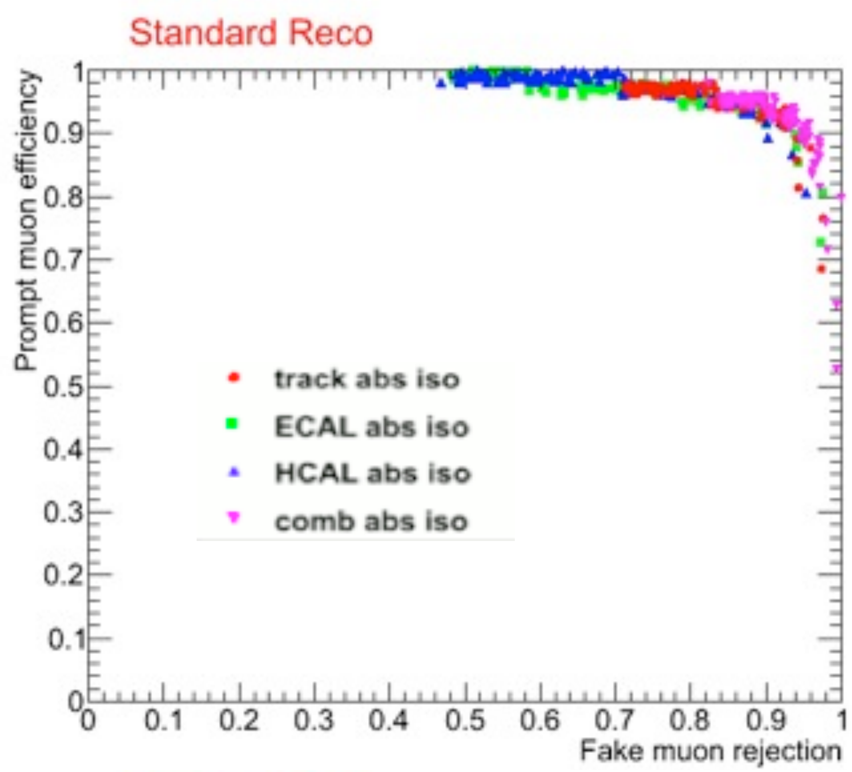
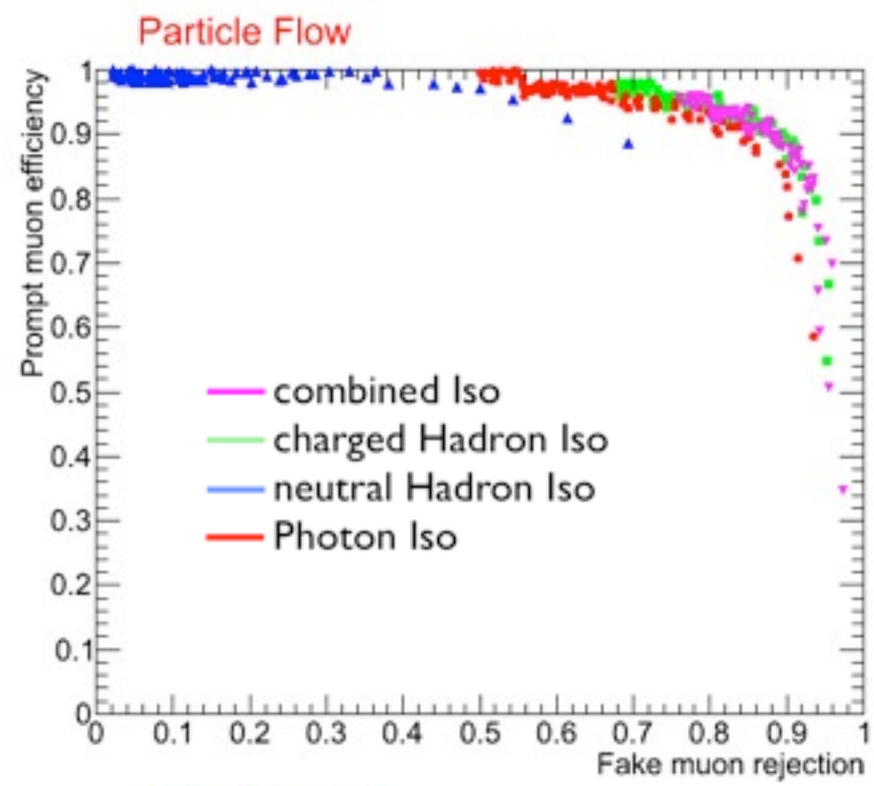
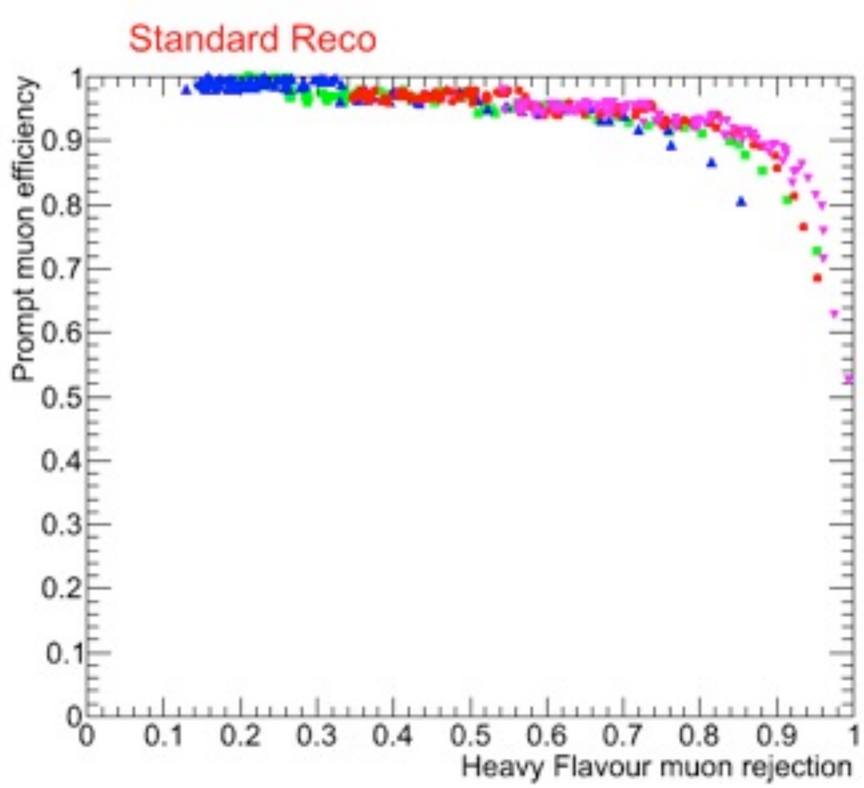
Efficiency vs Rejection

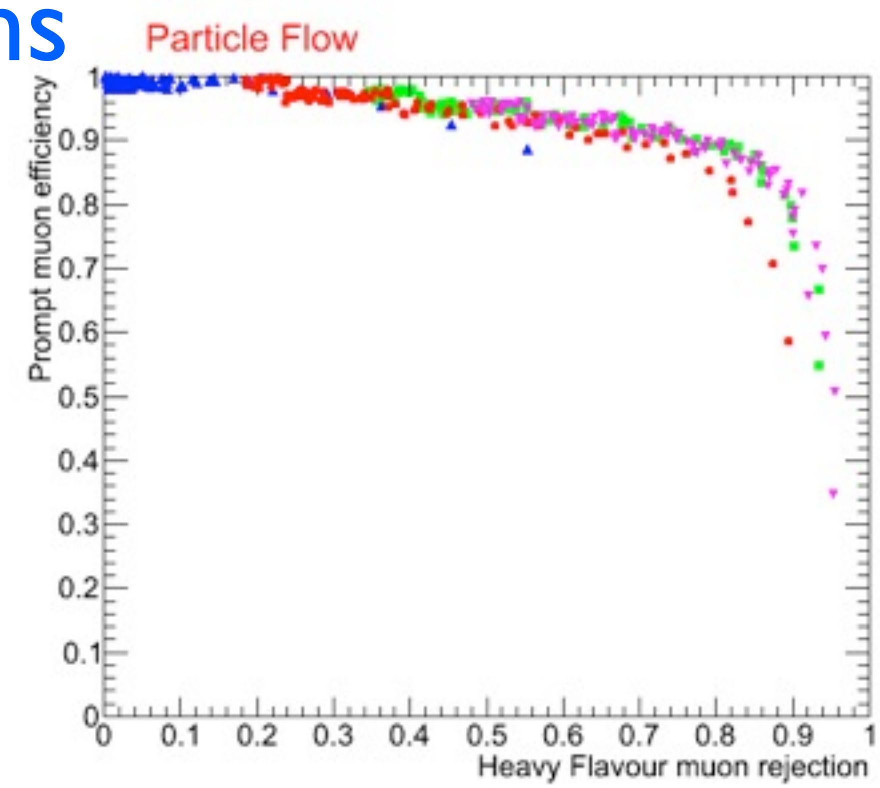
Pt from 2 to 30 GeV





Muons





Five Optimisation Approaches

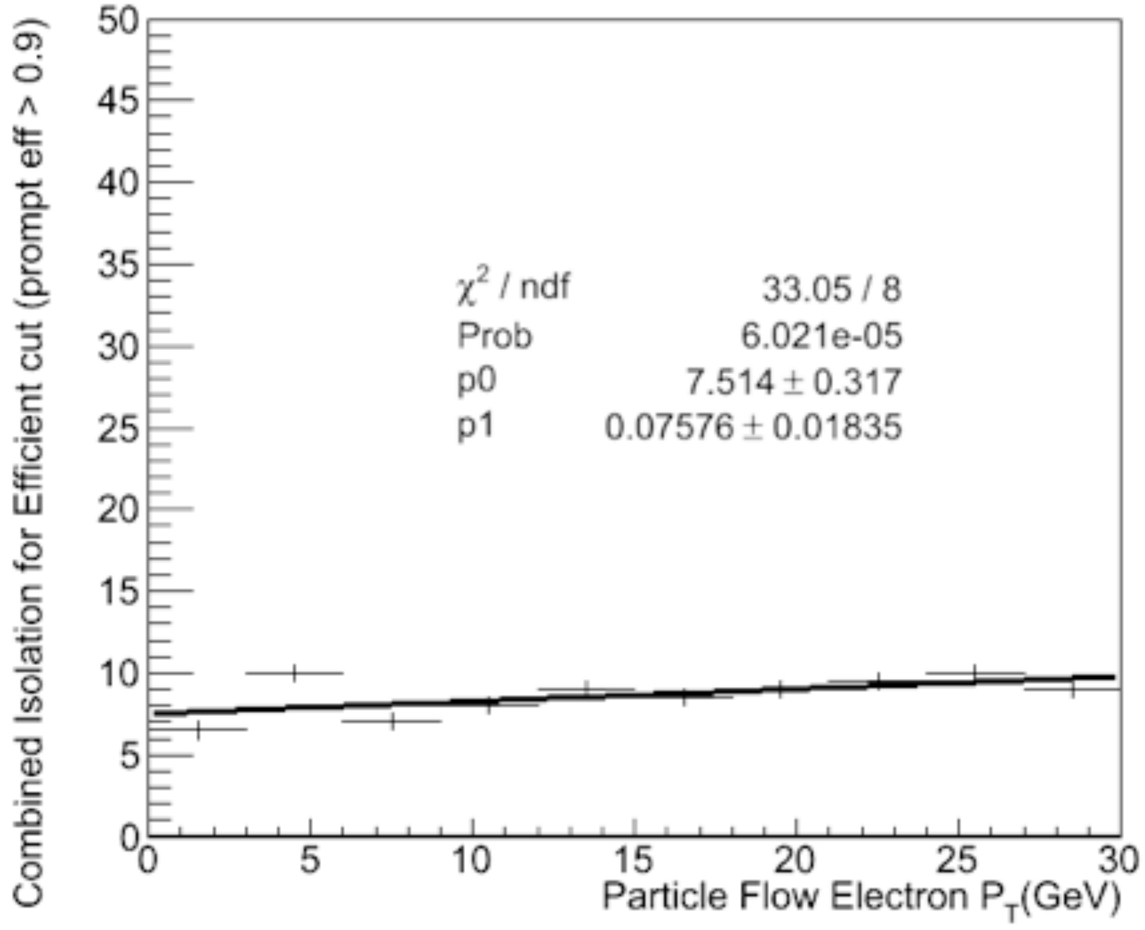
- We aim to have the same isolation performance for all the pt bins
- We consider different optimisation points because of the different needs of a SUSY leptonic analysis
  - We consider leptons with pt bigger than:
    - 10 GeV
    - 5 GeV
    - 2 GeV
- For each point we required

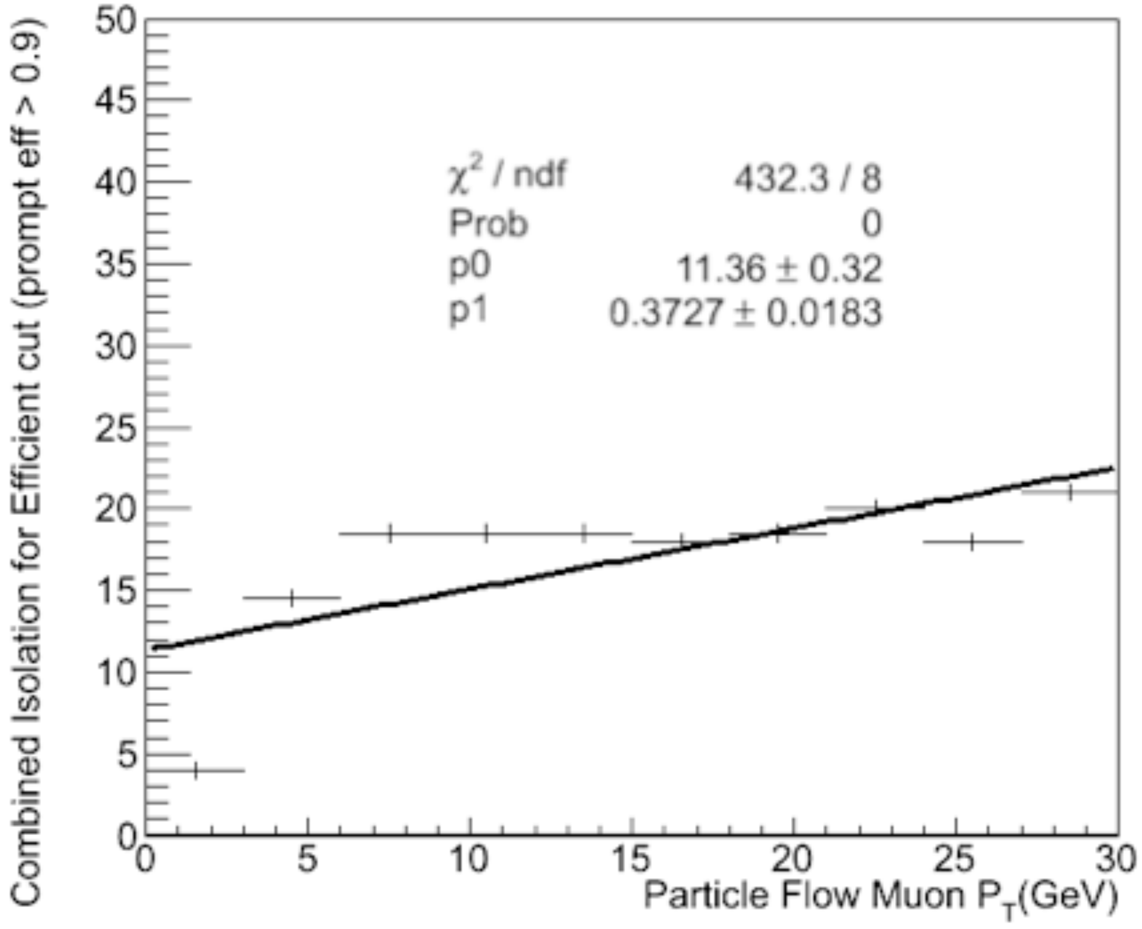
- **PureHeavyFlavor**
  Highest cut on isolation at which $\mathrm{rej}_{\text{heavy-flavor}} \geq 0.9$
- **PureFake**
  Highest cut on isolation at which $\mathrm{rej}_{\text{fake}} \geq 0.9$
- **Optimal**
  Minimizes $x = \sqrt{(1-\mathrm{eff})^2 + (1-\mathrm{rej}_{\text{fake}})^2}$
- **Efficient**
  Lowest cut on isolation at which $\mathrm{eff}_{\text{prompt}} \geq 0.9$
- **V+ jets**
  Combined relative Isolation < 0.1 and pt > 10 GeV

Efficient cut

- **Efficient**
  Lowest cut on isolation at which $\mathrm{eff}_{\mathrm{prompt}} \geq 0.9$

particle flow



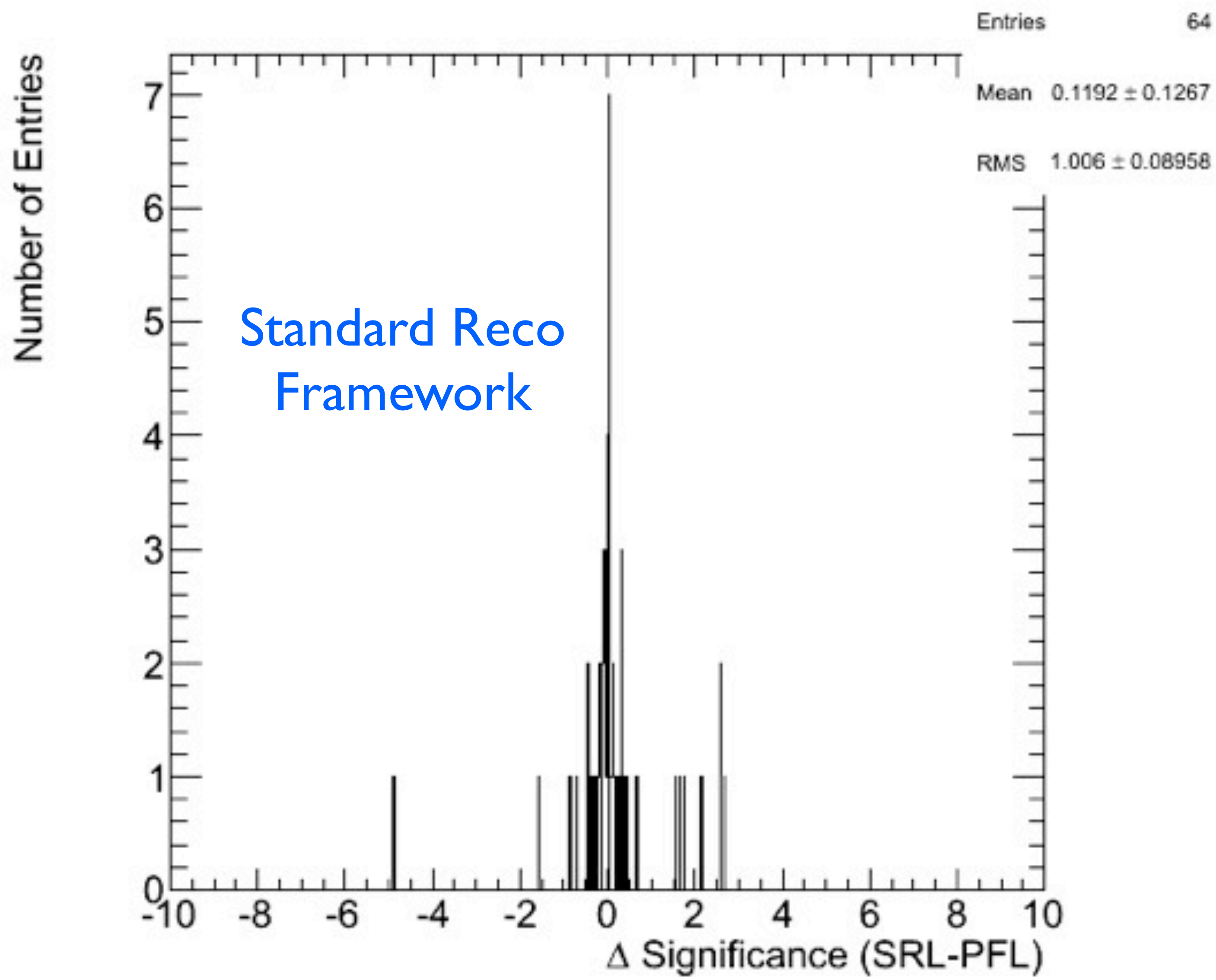


Applying to SUSY

- We applied the previous lepton selections in a few simple SUSY samples, in addition we required 3 jets with pt > 50 GeV and MET bigger than 50 or 100 GeV depending on the case.
- We worked with 64 SUSY cases which are:
    - 2 mSUGRA benchmarks, LM0 , LM1
    - 2 Single Lepton cases, electron, and muon.
    - 2 Double lepton cases, same sign and opposite sign double lepton with
        - ee, e-mu, mu-mu for each of them
    - 4 Isolation pt cuts
        - v+jets
        - optimal cut for different pt threshold
            - 10 GeV
            - 5Gev
            - 2Gev

Significance Changing only leptons

- We fixed Jets and MET in one of the frameworks and then study the variations in significance due to leptons only
- The significance was calculated for Single lepton selection, Same sign double lepton selection, and opposite sign double lepton selection.
- No significant difference between these two frameworks was observed.



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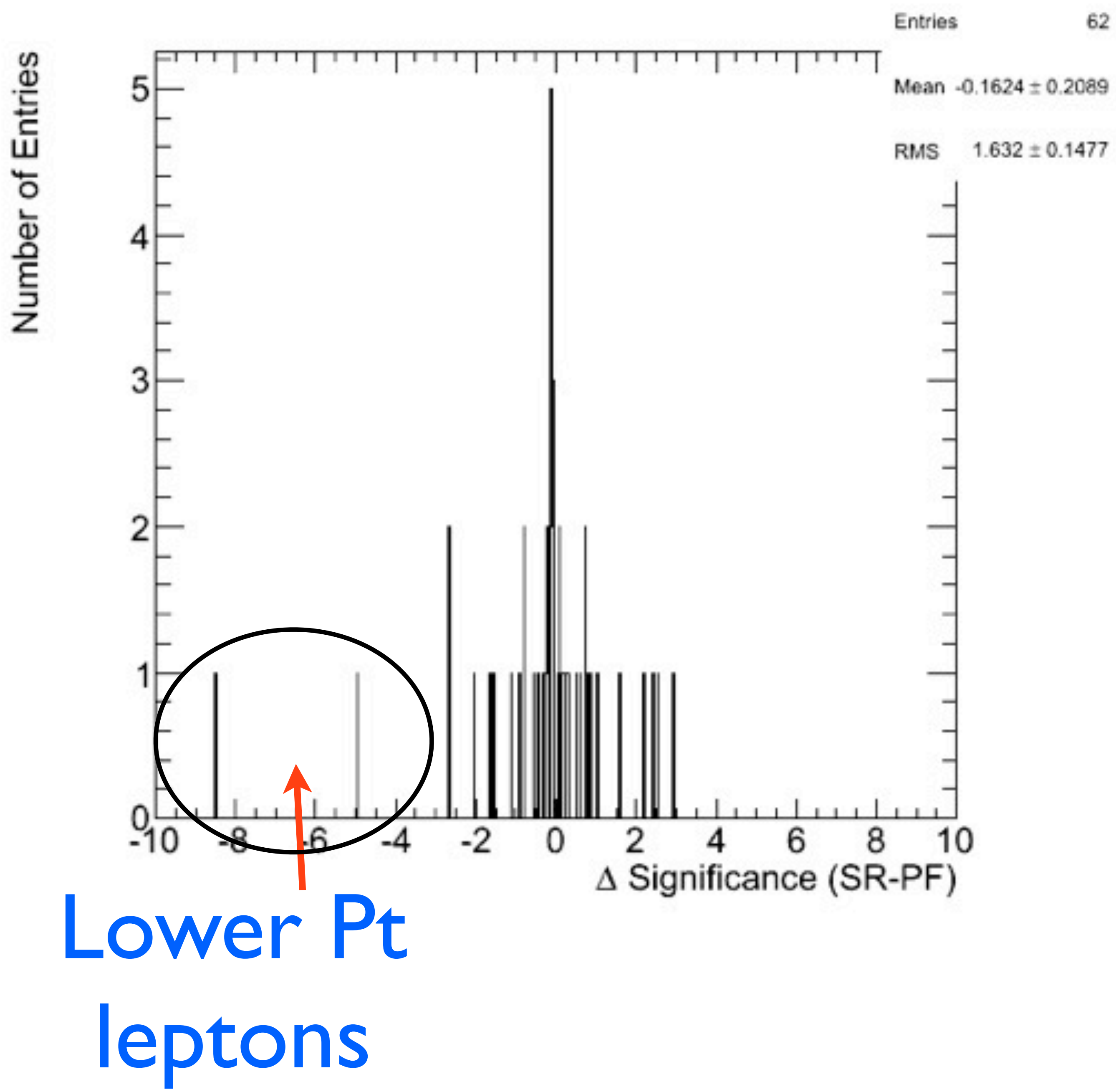
Significance Difference between frameworks revisited



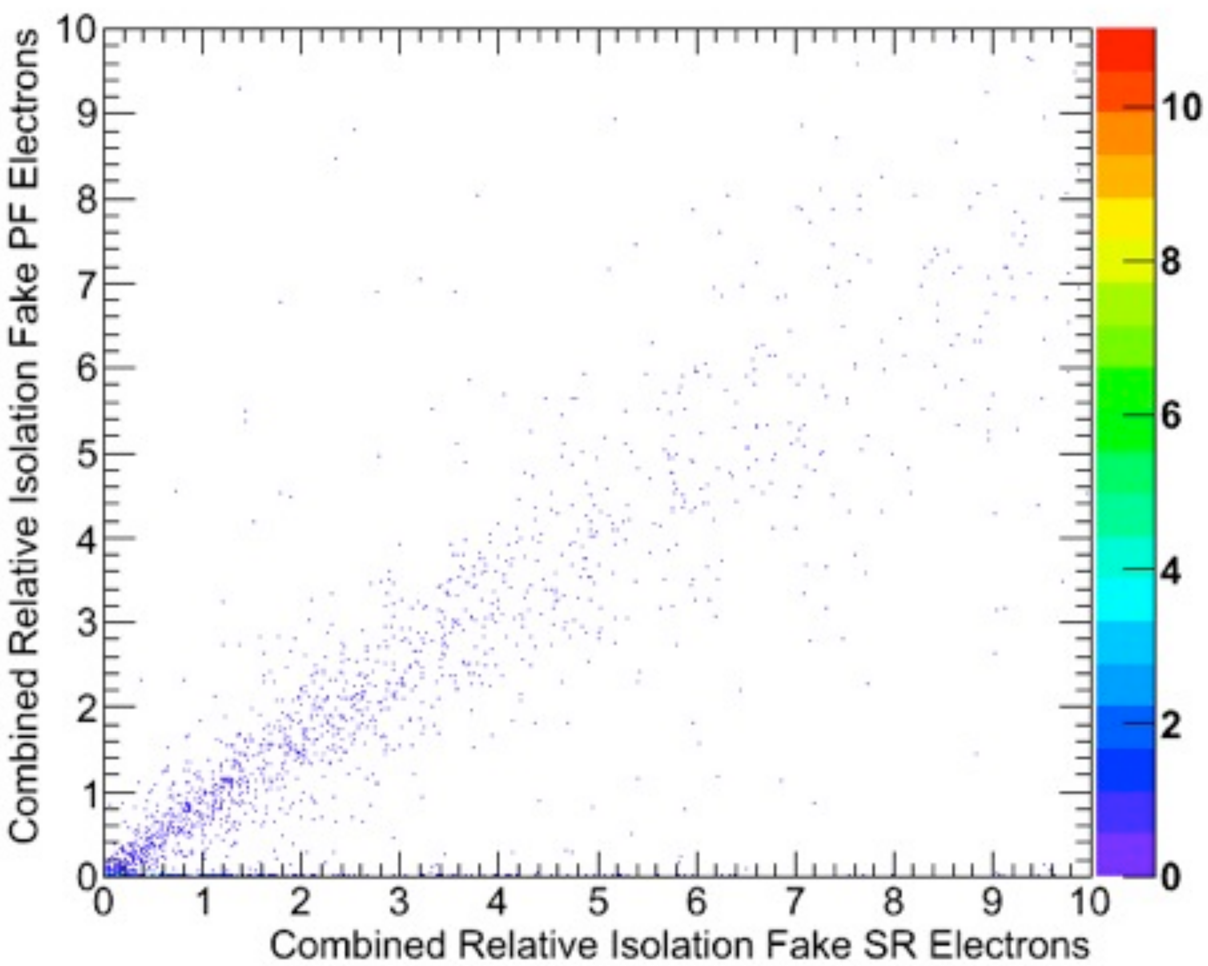
- Once a Standard RECO Jet cleaning is applied, the significance differences are not dramatic, however one can see some entries in the negative side of the plot, those cases corresponds to soft leptons.

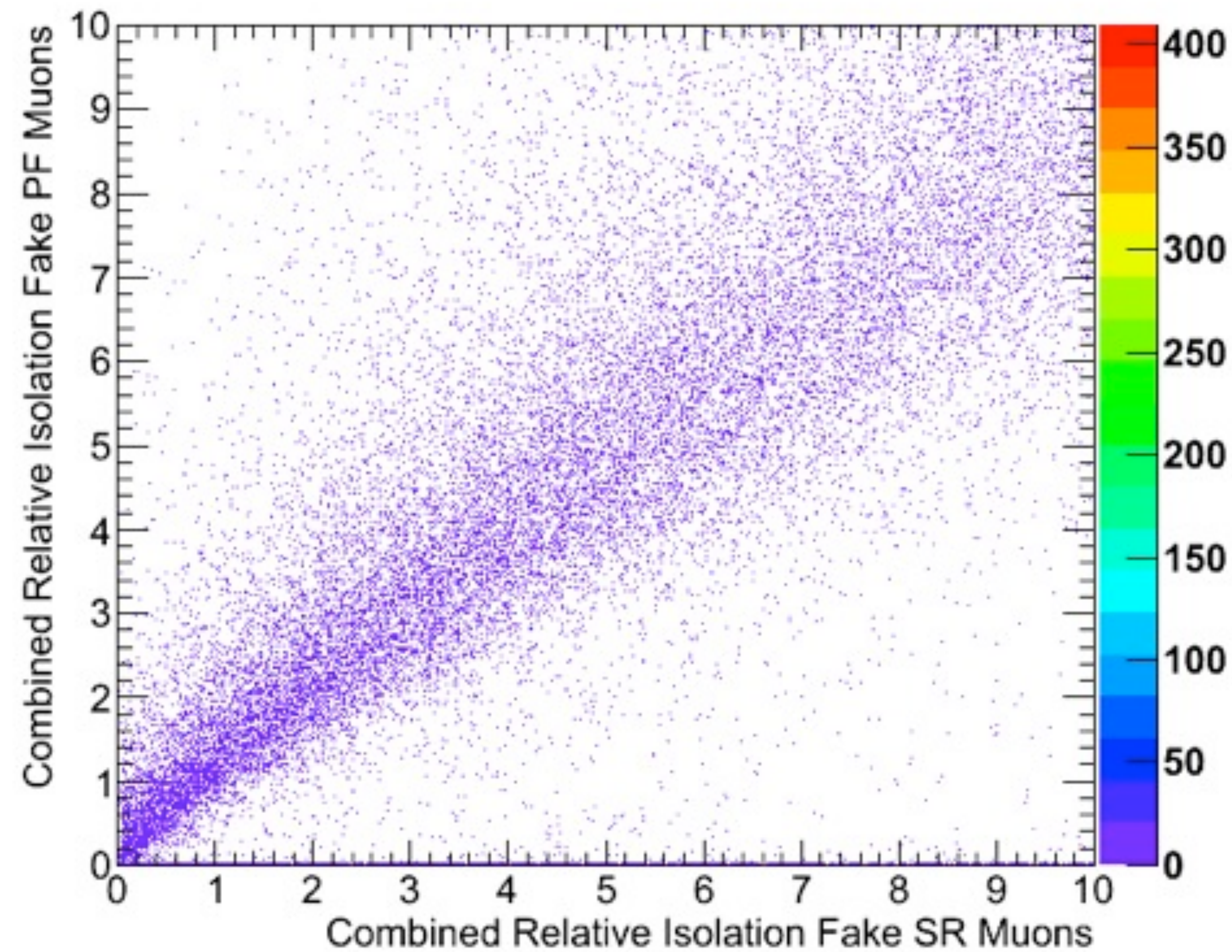
Conclusions

- The methods here described allow us to measure the optimal isolation cut in order to discriminate between prompt, fake and Heavy Flavour leptons.
- Results obtained in the CMS AN 2009-167 for Standard RECO leptons are very similar to the results we obtained with Particle Flow framework.
- PF2PAT out of the box behaves as standard PAT, any feedback... highly appreciated
- We observed an improvement for PF in the case the entire framework was used and the lepton pt cut was very loose.
- We plan to study the impact of the isolation variable as a discriminator between signal and background, this work is on going.

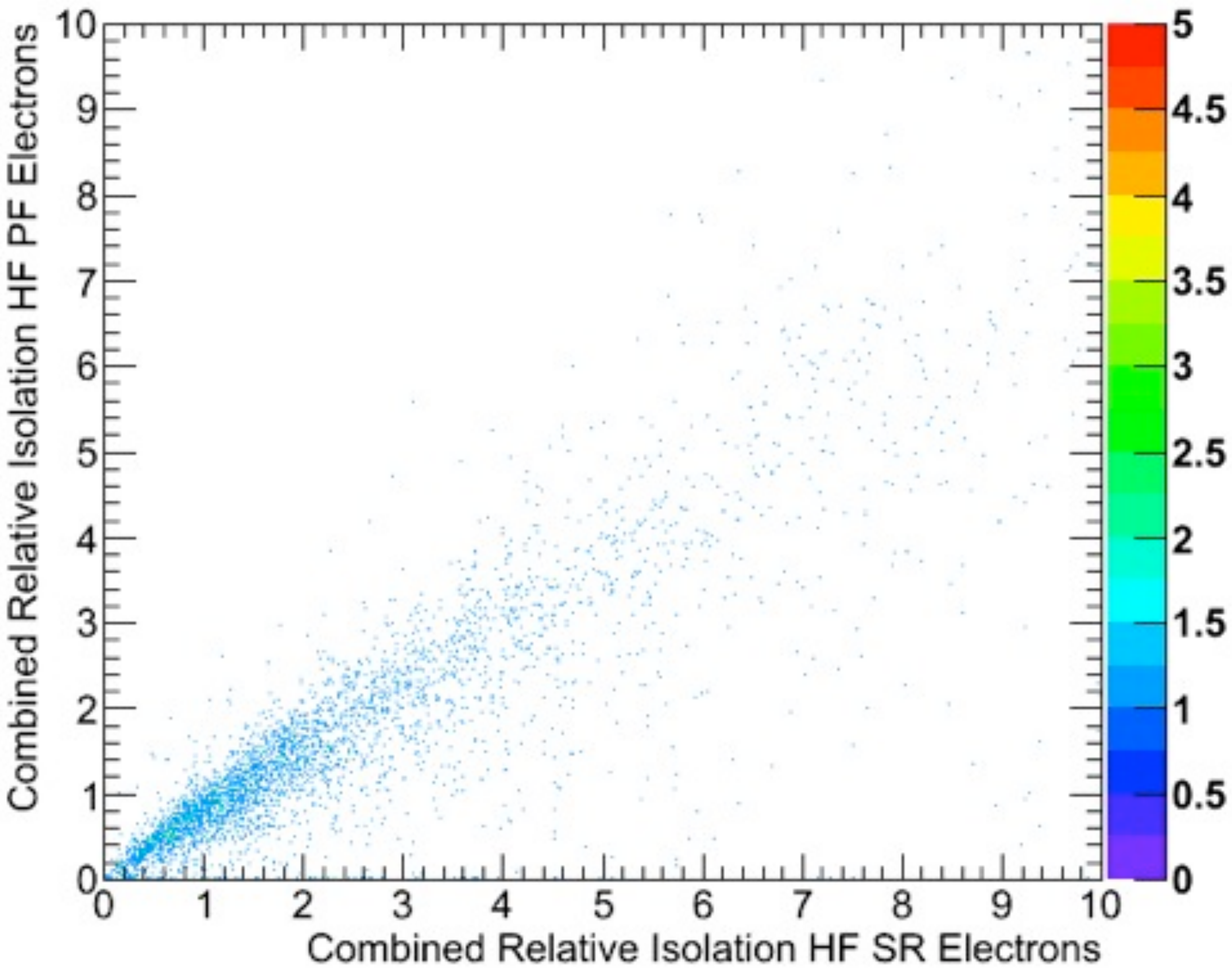
Backup

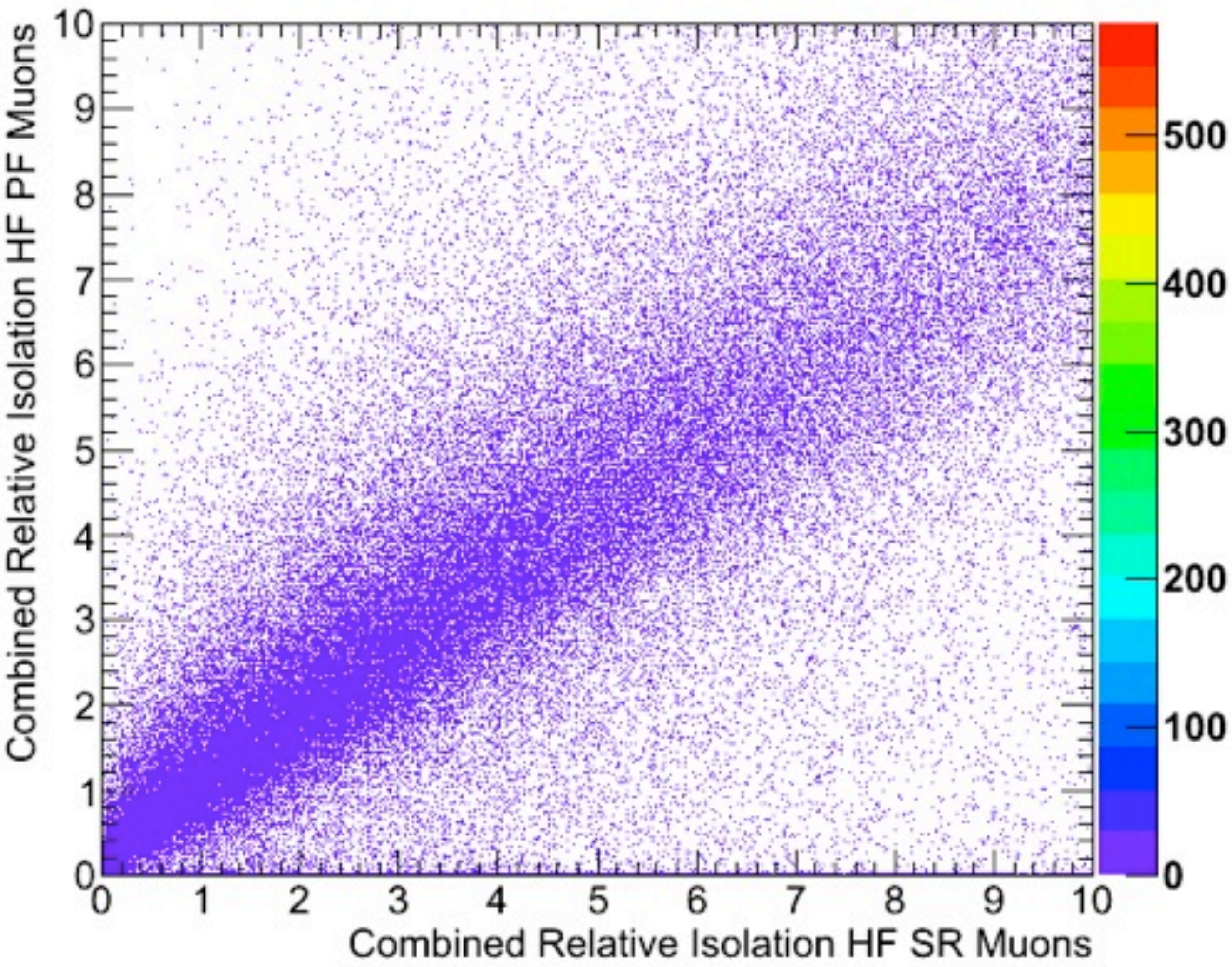
Combined Relative isolation fake



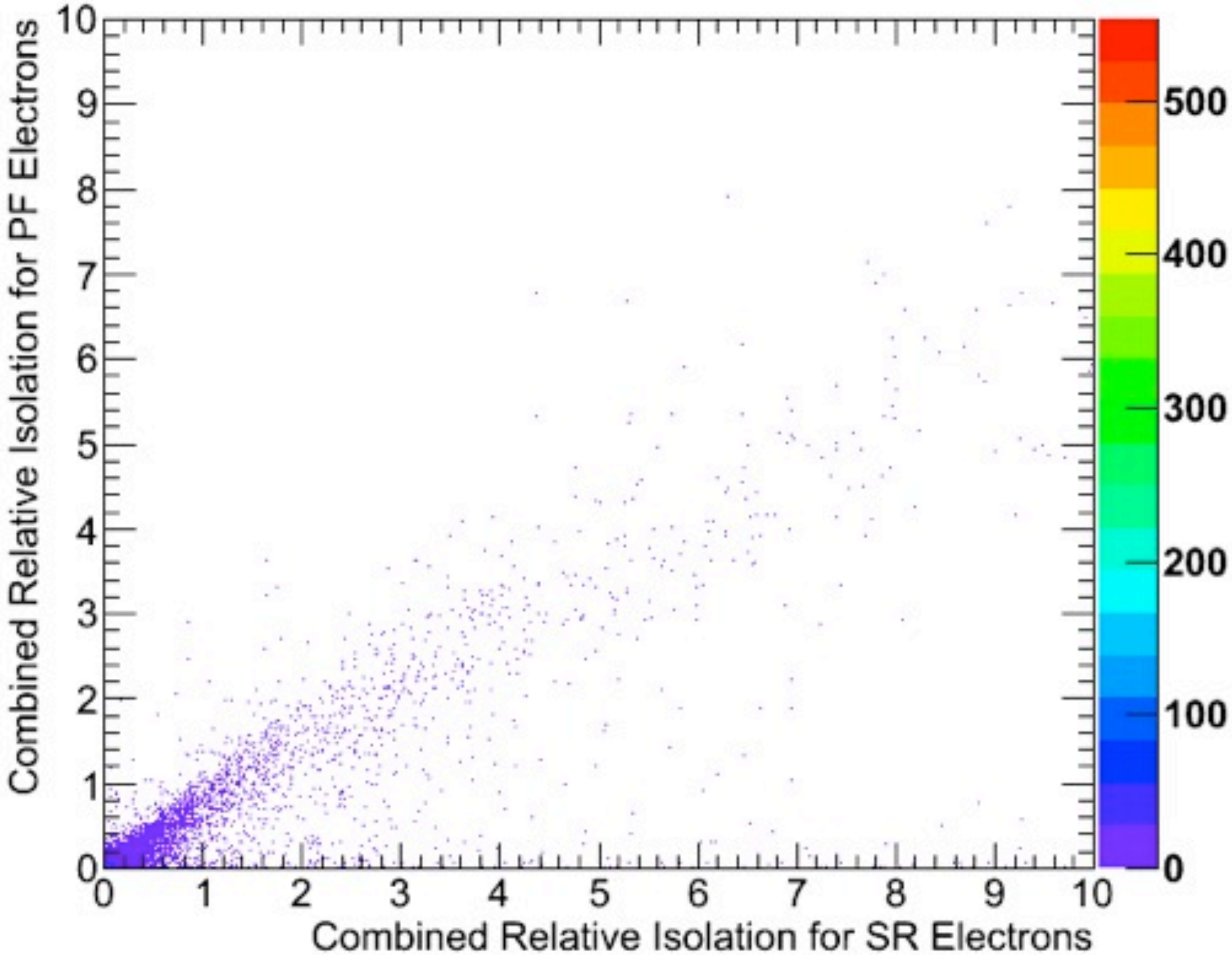


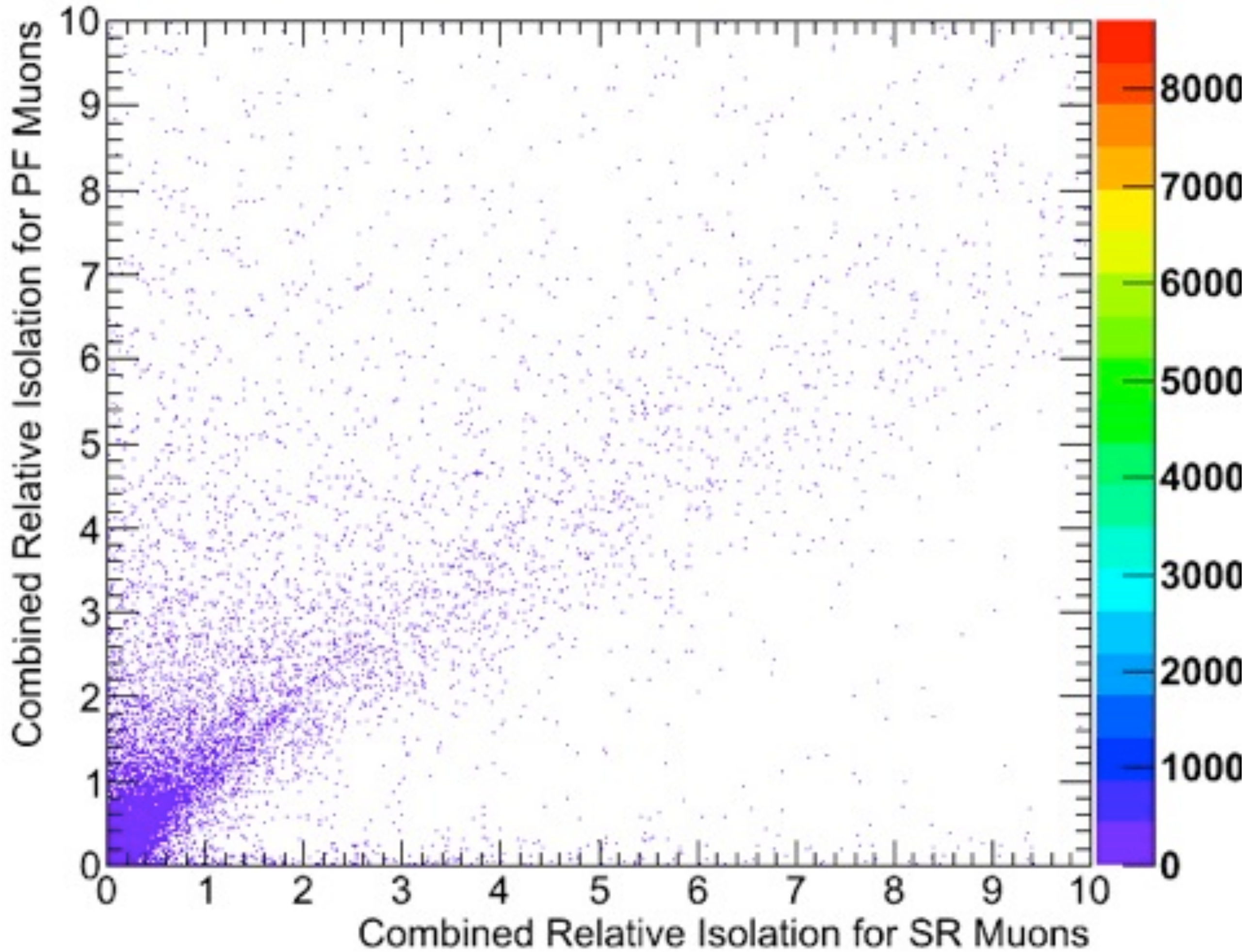
Combined Relative isolation HF





Combined Relative isolation prompt

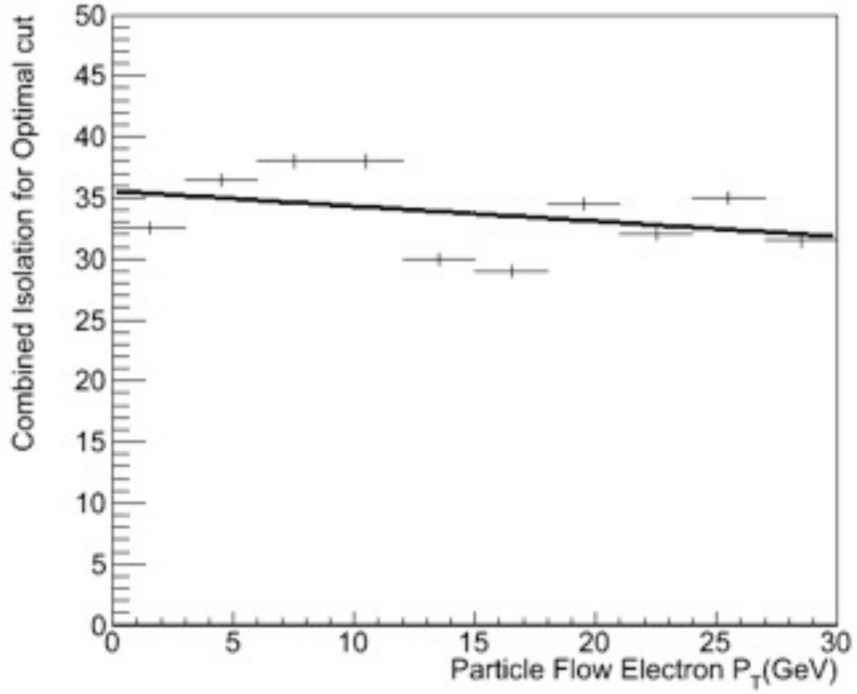




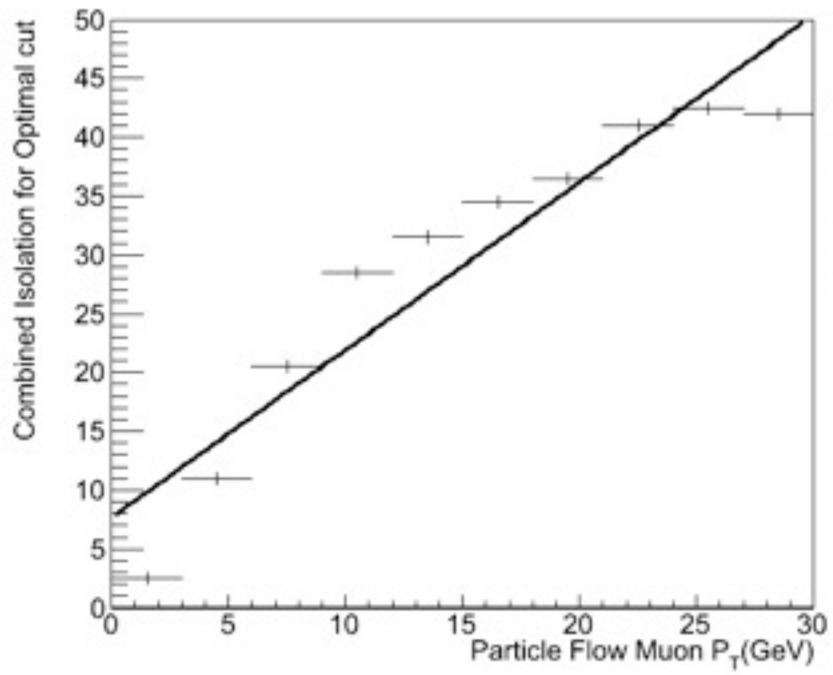
Optimal cut

- **Optimal**
  Minimizes $x = \sqrt{(1-\mathrm{eff})^2 + (1-\mathrm{rej}_{\mathrm{fake}})^2}$

particle flow



χ^2 / ndf	323.3 / 8
Prob	0
p0	35.55 ± 0.32
p1	-0.1232 ± 0.0183

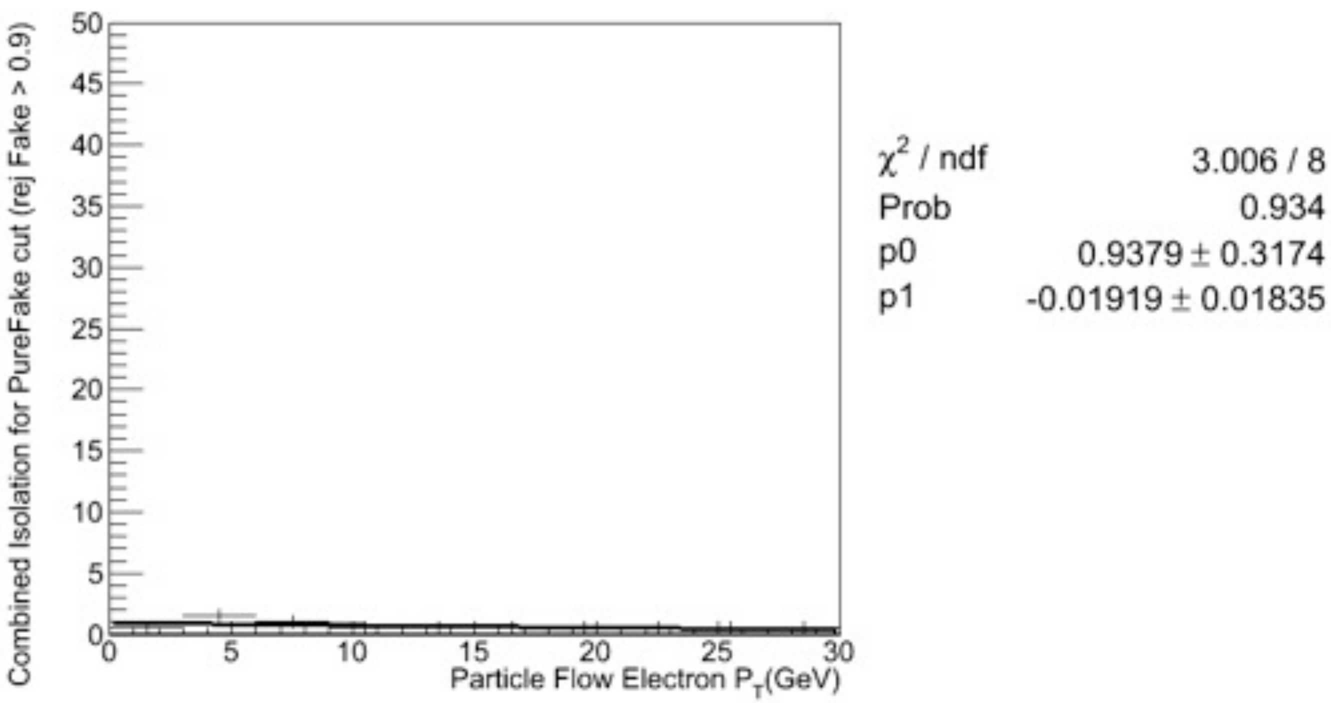


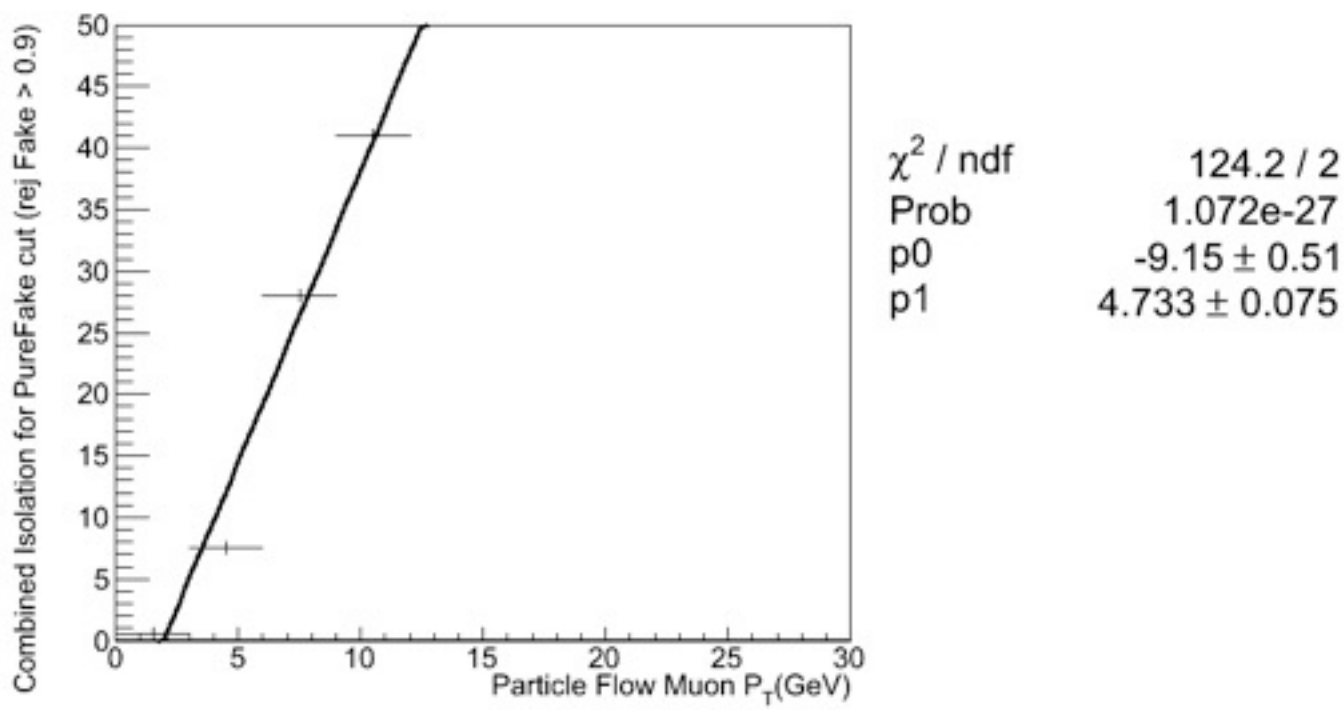
χ^2 / ndf	713.8 / 8
Prob	0
p0	7.671 ± 0.317
p1	1.425 ± 0.018

Pure Fake cut

- **PureFake**
  Highest cut on isolation at which $rej_{fake} \geq 0.9$

particle flow

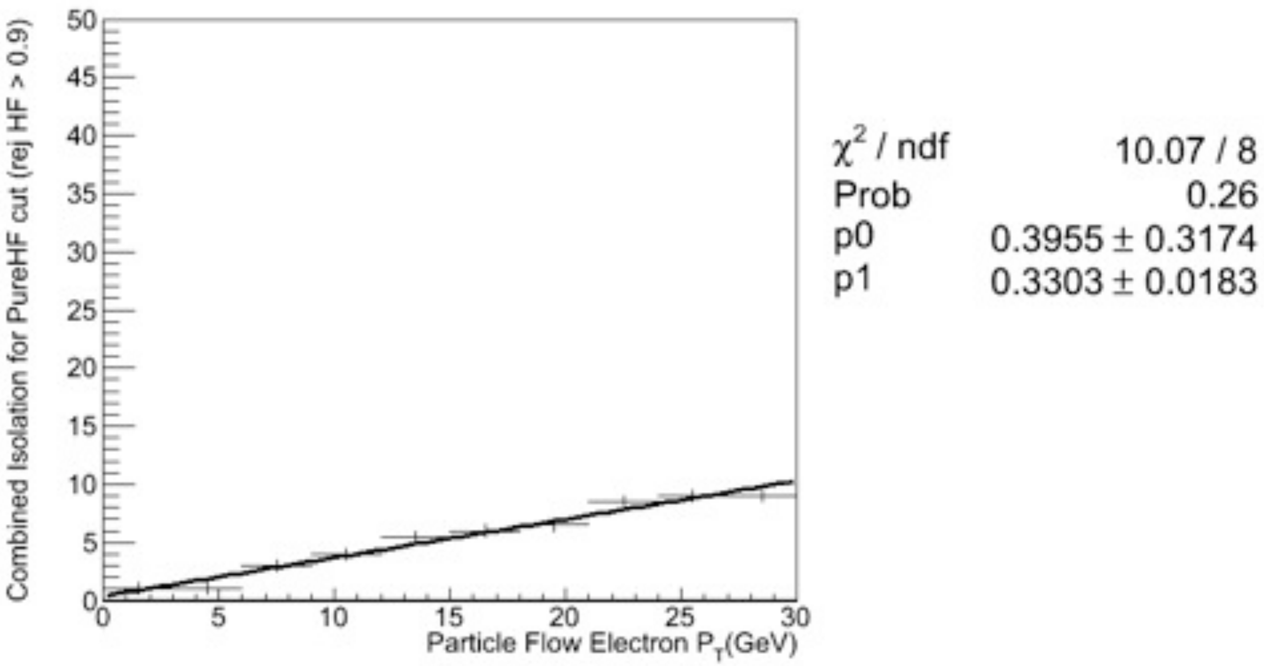


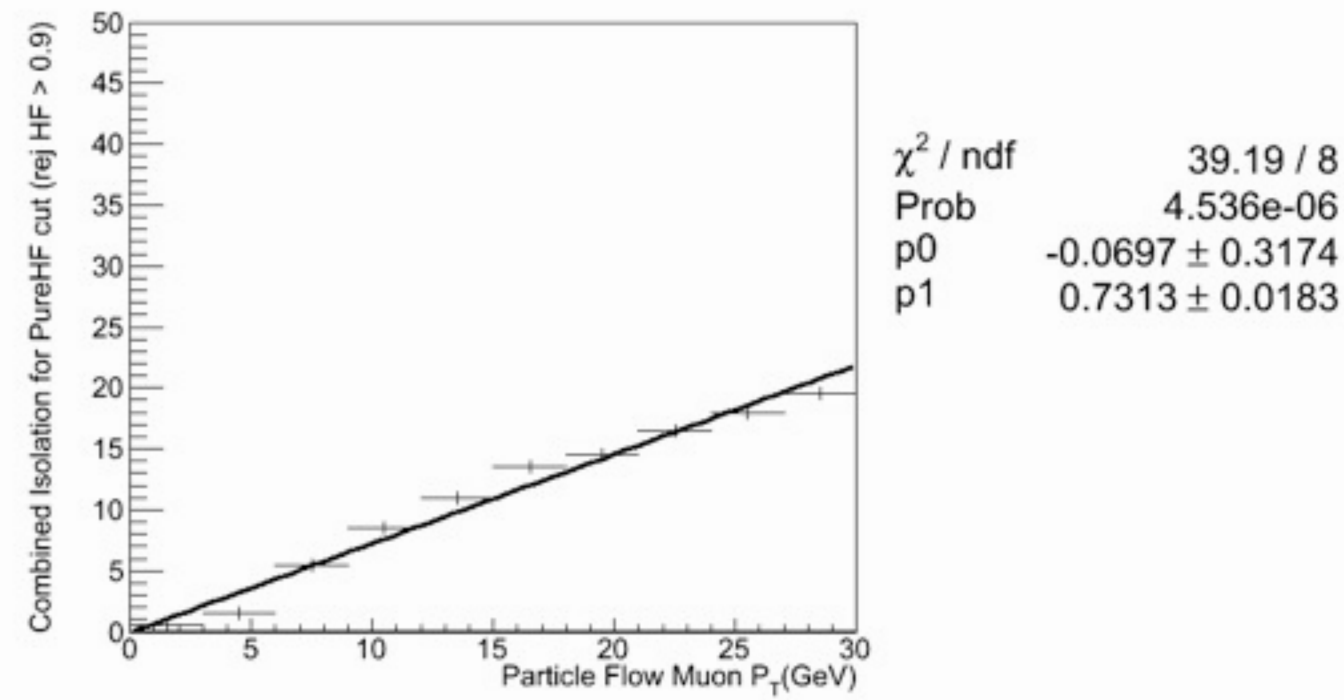


Pure HF cut

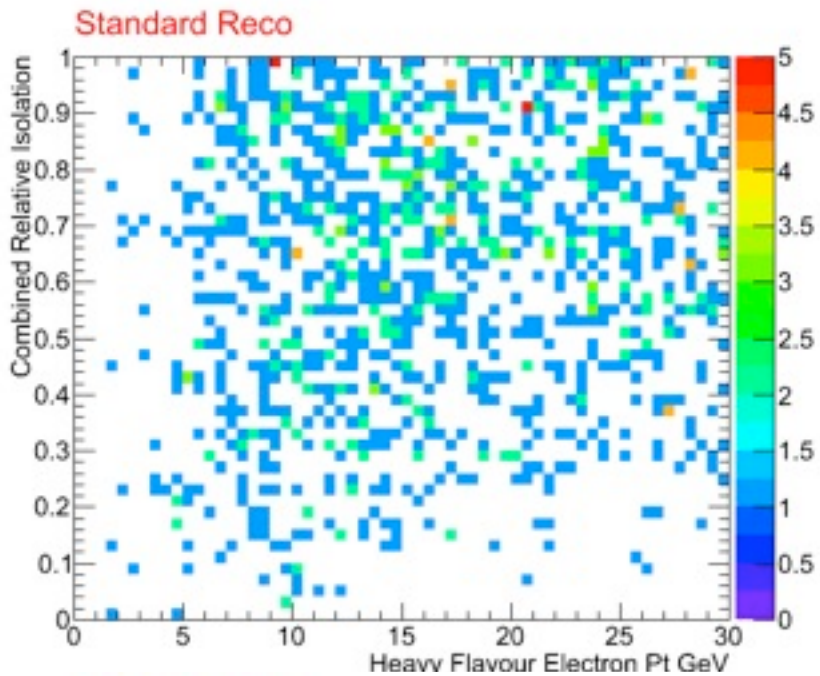
- **PureHeavyFlavor**
  Highest cut on isolation at which $\mathrm{rej}_{\text{heavy-flavor}} \geq 0.9$

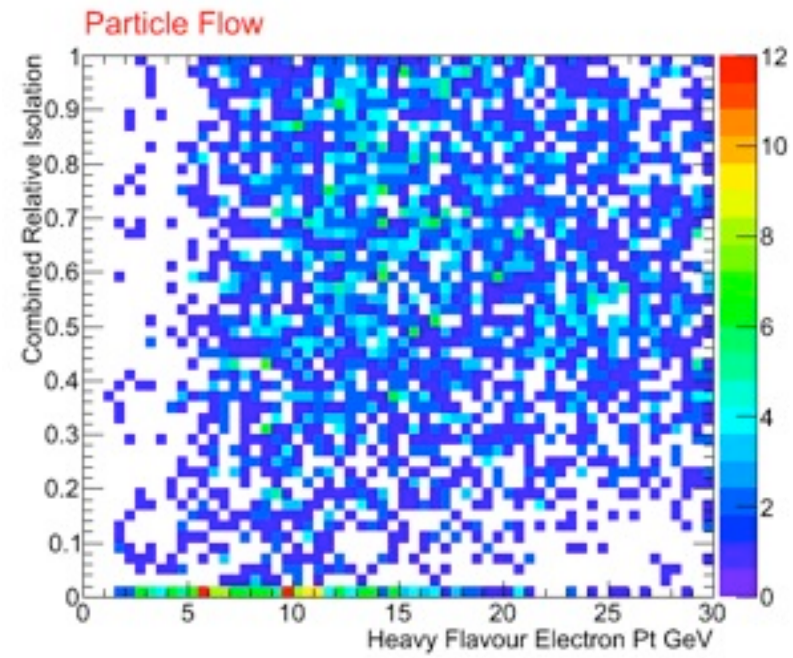
particle flow

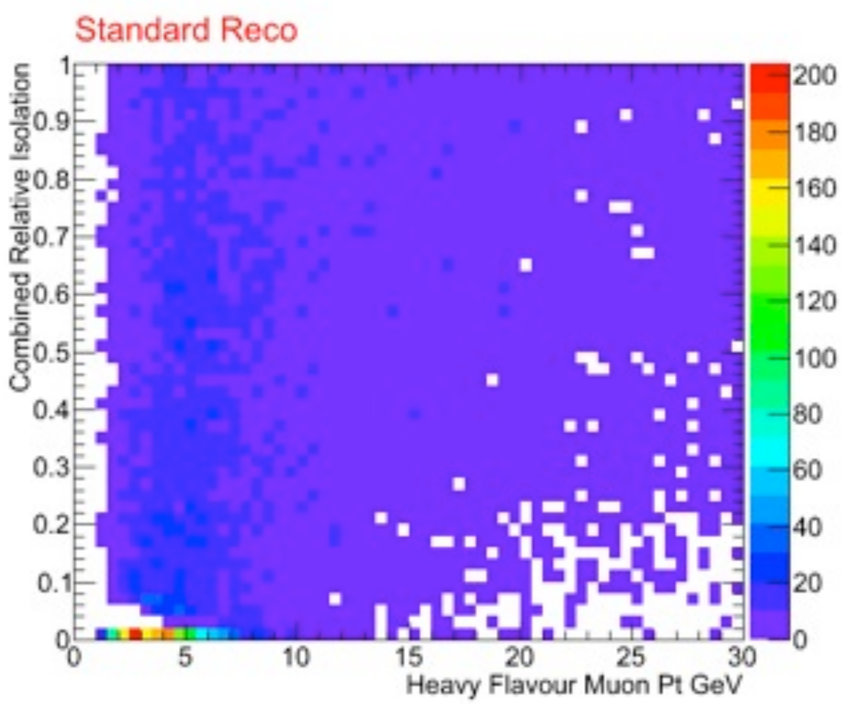


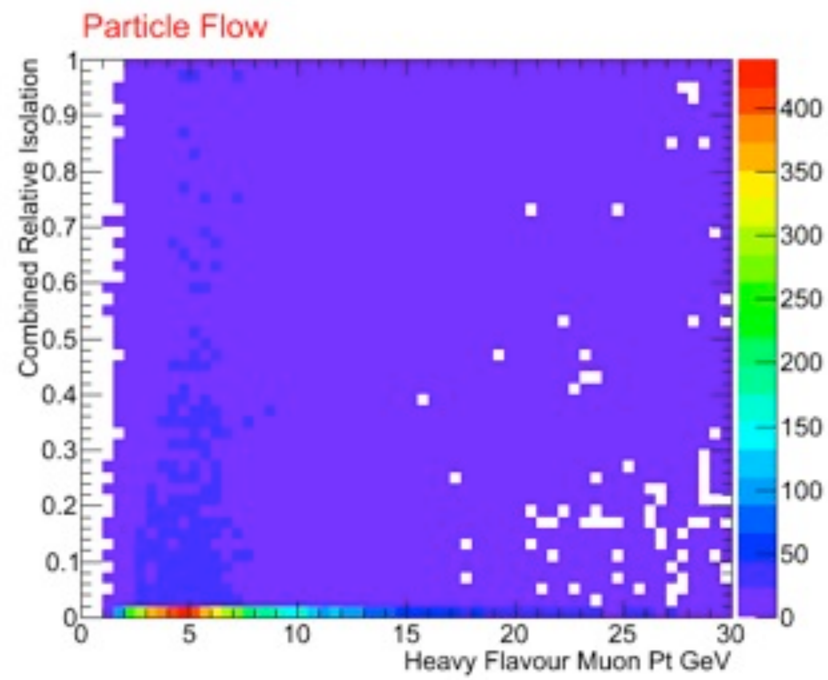


Combined Relative Isolation HF









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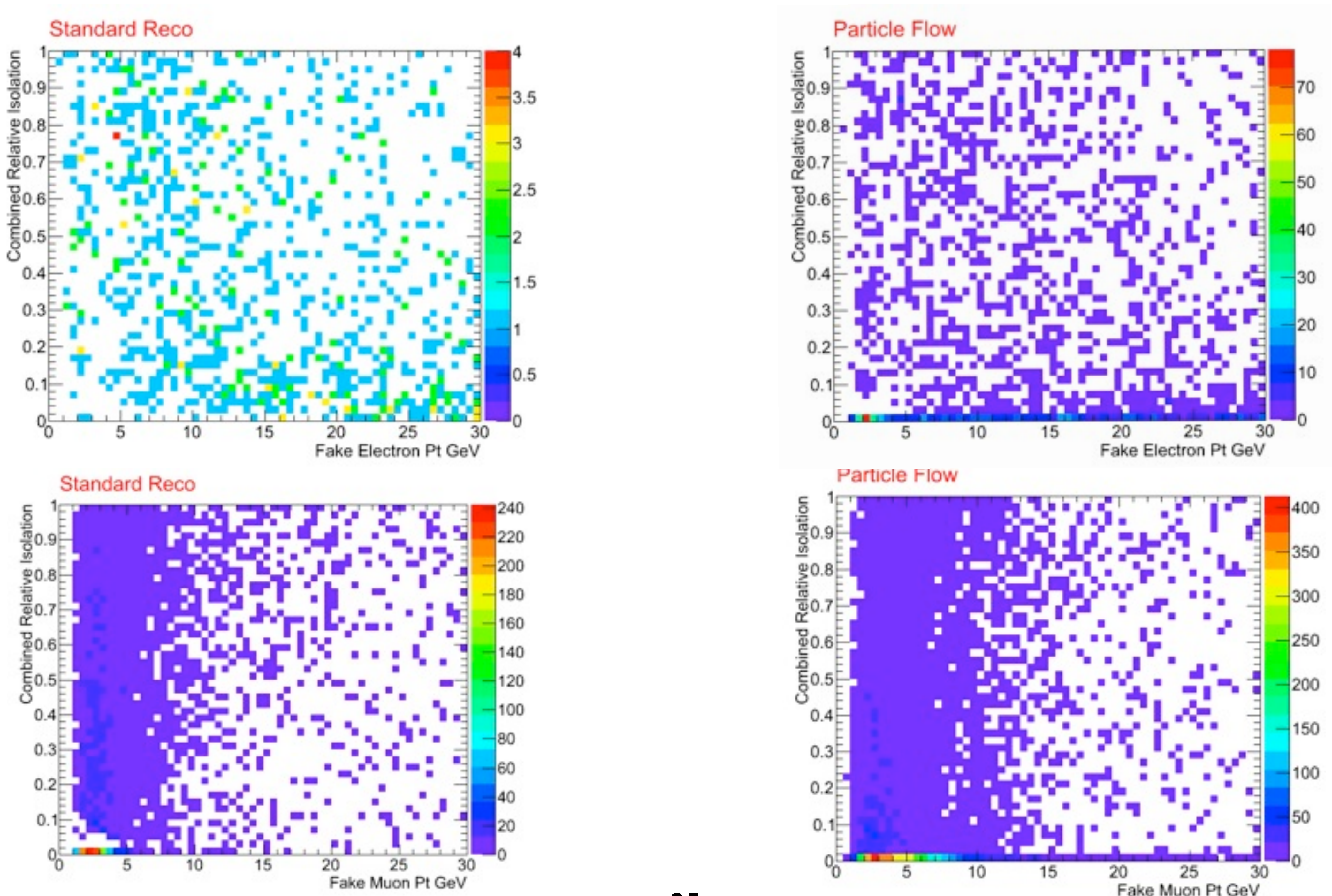
Combined Relative Isolation Fake



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